The Longitudinal Influence of Social Determinants of Health on Glycemic Control in Elderly Adults With Diabetes

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OBJECTIVE

This study aimed to understand the longitudinal relationship between financial, psychosocial, and neighborhood social determinants and glycemic control (HbA_{1c}) in older adults with diabetes.

RESEARCH DESIGN AND METHODS

Data from 2,662 individuals with self-reported diabetes who participated in the Health and Retirement Study (HRS) were used. Participants were followed from 2006 through 2014. Financial hardship, psychosocial, and neighborhood-level social determinant factors were based on validated surveys from the biennial core interview and RAND data sets. All social determinant factors and measurements of HbA_{1c} from the time period were used and treated as time varying in analyses. SAS PROC GLIMMIX was used to fit a series of hierarchical linear mixed models. Models controlled for nonindependence among the repeated observations using a random intercept and treating each individual participant as a random factor. Survey methods were used to apply HRS weighting.

RESULTS

Before adjustment for demographics, difficulty paying bills ($\beta = 0.18$ [95% CI 0.02, 0.24]) and medication cost nonadherence (0.15 [0.01, 0.29]) were independently associated with increasing HbA_{1c} over time, and social cohesion (−0.05 [−0.10, −0.001]) was independently associated with decreasing HbA_{1c} over time. After adjusting for both demographics and comorbidity count, difficulty paying bills (0.13 [0.03, 0.24]) and religiosity (0.04 [0.001, 0.08]) were independently associated with increasing HbA_{1c} over time.

CONCLUSIONS

Using a longitudinal cohort of older adults with diabetes, this study found that financial hardship factors, such as difficulty paying bills, were more consistently associated with worsening glycemic control over time than psychosocial and neighborhood factors.

Diabetes is a major source of morbidity and the seventh leading cause of death in the U.S. (1,2). Most recent estimates show that >14% of the adult U.S. population have diabetes, with medical and societal costs expected to continue to increase to >$600 billion by 2030 (2,3). Individuals with diabetes require comprehensive management that occurs both within and outside the health care system to prevent or delay

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complications such as kidney failure, cardiovascular disease, amputation, or stroke (1,4).

There is a growing recognition that the social determinants of health, defined by the World Health Organization as "conditions in which people are born, grow, work, live, and age," have an important influence on individuals' ability to complete self-management behaviors and therefore minimize complications of diabetes (5,6). Social determinants are often categorized into four groups of interacting factors: *1*) socioeconomic circumstances, *2*) psychosocial factors, *3*) neighborhood environment, and *4*) political, economic, and cultural drivers (6). Existing research has found associations between socioeconomic status and related factors, such as food insecurity, with access to care and poor health status in adults with diabetes (7–13). In addition, psychosocial factors, such as social support, health literacy, depression, and anxiety, have been associated with diabetes prevalence, adherence to self-management recommendations, access to regular health care, and glycemic control (14–19). Less evidence links the neighborhood environment to diabetes outcomes, although more recent analyses have indicated that there are possible relationships, for example through changes in access to supermarkets or improving community cohesion (20–25).

One of the major limitations in understanding the role of social determinants on diabetes outcomes is longitudinal or interventional evidence to explain the direction and mechanisms of influence (7,26–28). An analysis of financial strain over the life course found that persistence of financial hardship is associated with poor health in older adults and is more important than episodic hardship in predicting poor outcomes (29). A multilevel modeling approach was used to investigate the influence of neighborhood factors on diabetes outcomes and found that social disorganization was associated with poor glycemic control, and neighborhoods with high economic disadvantage were associated with increased use of emergency health services (18). In addition, a retrospective cohort study of >15,000 individuals with diabetes conducted in 734 communities in Pennsylvania found that high socioeconomic deprivation, poor food access/availability, and lack of recreational assets were associated with poor glycemic control (30). Many studies, however, have not accounted for additional social determinant factors that could explain the relationship. For example, longitudinal relationships found between food insecurity and health care use in older adults were attenuated by socioeconomic factors, and factors such as social support have been found to buffer the influence of depressive symptoms on glycemic control (31,32). Given the limited evidence using a variety of social determinants over time to understand the drivers of poor glycemic control, the aim of this study was to understand the longitudinal relationship between financial, psychosocial, and neighborhood social determinants and glycemic control (HbA_{1c}) in older adults with diabetes.

RESEARCH DESIGN AND METHODS

Data Source and Study Population

The Health and Retirement Study (HRS) is a longitudinal project sponsored by the National Institute on Aging and the Social Security Administration (33). In its original conceptualization, the HRS survey was designed to follow age-eligible individuals and their spouses or partners as they made the transition from active worker into retirement to examine the dynamic interactions among health, family, and economic variables in the postretirement period at the end of life (33). Enrollments occurred staggered by birth cohort in 1992 (HRS), 1993 (AHEAD [Asset and Health Dynamics Among the Oldest Old]), 1998 (CODA [Children of the Depression] and WB [War Babies]), 2004 (EBB [Early Baby Boomers]), and 2010 (MBB [Mid Baby Boomers]). Biennial interviews were conducted through 2014 (28). The enhanced face-to-face (EFTF) interview includes a set of physical performance measures, collection of biomarkers, and a Leave-Behind Questionnaire on psychosocial topics (29). A random one-half of households were preselected for the EFTF in 2006, with the other one-half of the sample selected for 2008. From that point on, every household will repeat the EFTF portion every other wave (33).

This study included HRS participants with EFTF interviews from 2006 to 2014. Participants (n = 12,725) who were ages ≥50 years participated in blood-based biomarker data collection in the first EFTF interview. Among them, 2,725 self-reported with diagnosed diabetes. After excluding those without HbA_{1c} values measured, 2,662 participants were identified for this analysis. Data reported by the participants were followed from 2006 through 2014, providing a total of 5,028 interviews with HbA_{1c} test results for selected participants.

Primary Outcome

The primary outcome for this study was glycemic control (HbA_{1c} level) for individuals who self-reported diabetes in response to the question, "Has a doctor ever told you that you have diabetes or high blood sugar?" Multiple measurements of HbA_{1c} occurred during the time period, and all measurements for individuals in the cohort were included in the analysis. HbA_{1c} was assayed from dried blood spot (DBS) samples collected during the EFTF interview. Because the resulting biomarker values that are based on DBS vary across assays and laboratories and may be quite different from the more conventionally used whole-blood assays, HRS constructed and released a National Health and Nutrition Examination Survey (NHANES)–equivalent assay value for each assay and recommended the NHANES-equivalent assay values for analytic use (34). We used the NHANES-equivalent HbA_{1c} for analysis. We treated the baseline and subsequent HbA_{1c} measurements as repeated measures and analyzed them in a longitudinal repeated-measures analysis.

Social Determinant Factors

Financial hardship, psychosocial, and neighborhood-level social determinant factors located in the biennial core interview and RAND data sets were used. Multiple measurements of some social determinant factors occurred during the time period and were incorporated as time varying to correspond to the response appropriate for each measurement time. All measures were created on the basis of documentation material from the HRS (33–35).

Financial hardship variables included three single questions indicating *1*) difficulty paying bills, *2*) food insecurity, and *3*) medication cost nonadherence.

1. Difficulty paying bills was based on the question, "How difficult is it for you to meet monthly payments on your/your family's bills?" Response options of somewhat, very, or completely difficult were considered as difficulty paying bills.
2. Food insecurity was based on the question, "Since your last interview or in the last 2 years, have you always had enough money to buy the food you need?" No indicated food insecurity.

3. Medication cost nonadherence was based on the question, "At any time since the last interview or in the last 2 years, have you ended up taking less medication than was prescribed for you because of the cost?" Yes indicated cost nonadherence.

Psychosocial factors included scales measuring *1*) religiosity, *2*) efficacy over health, *3*) social support (separated into positive social support score and negative social support score), *4*) depression, and *5*) loneliness (35).

1. Religiosity was based on a scale range of 1–6, which asks respondents the level to which they agree with the statements: "I believe in a God who watches over me," "the events in my life unfold according to a divine or greater plan," "I try hard to carry my religious beliefs over into all my other dealings in life," and "I find strength and comfort in my religion." Scores are determined by averaging the response across all four items, and higher scores indicate higher levels of religiosity.
2. Efficacy over health was based on a scale with a range of 0–10, using the response to the question, "How would you rate the amount of control you have over your health these days?" Higher scores indicate higher levels of control.
3. Social support was based on a set of seven items asking about perceived support across spouses, children, family, and friends. Three questions were used to measure positive social support, including really understanding the way you feel, relying on them for a serious problem, and opening up to them if you need to talk about worries, with higher scores on a scale of 1–4 indicating more positive support. Four questions were used to measure negative social support, including how often people make too many demands, criticize, let you down, or get on your nerves, with higher scores on a scale of 1–4 indicating more negative support. The final scores for each dimension were found by averaging responses across all possible sources of support.
4. Depression was measured using the Center for Epidemiologic Studies Depression (CESD) scale. The CESD score is the sum of five negative indicators minus two positive indicators. The negative indicators measure whether the respondent experienced the following sentiments all or most of the time: feels depressed, everything is an effort, sleep is restless, feels alone, feels sad, and cannot get going. The positive indicators measure whether the respondent felt happy and enjoyed life all or most of the time. The CESD score was constructed by HRS on the basis of responses to the CESD questions, with higher scores indicating more depressive symptomology.
5. Loneliness was based on the three-item UCLA Loneliness scale, which gives a final score ranging from 1 to 3, with higher numbers indicating more loneliness. Questions ask whether the respondent lacks companionship, feels left out, or feels isolated from others. Scores are determined by averaging the scores across all three reverse-coded items.

Neighborhood factors included scales for *1*) neighborhood social cohesion, *2*) social participation, *3*) neighborhood physical disorder, and *4*) perceived everyday discrimination (35).

1. Neighborhood social cohesion was based on a four-item scale that ranges from 1 to 7. The scale asks whether respondents feel part of the area, trust people, feel people are friendly, and feel people will help them. Scores are determined by reverse scoring all four items and averaging the scores across all four items so that higher scores indicate more social cohesion.
2. Social participation was based on the frequency with which individuals participate in 18 different activities, such as activities with grandchildren, volunteer work, educational courses, sports, meetings of nonreligious or religious groups, playing games, doing gardening, and going for walks. Scores are determined by summing the number of activities a respondent participated in so that the scale ranged from 0 to18, with higher scores indicating more social participation.
3. Neighborhood physical disorder was based on a four-item scale asking about vandalism/graffiti, rubbish, vacant/deserted houses, and crime in their neighborhood. Scores are determined by averaging the response across all four items for a range of 0 to 7, with higher scores indicating more disorder.
4. Perceived everyday discrimination was based on six items asking about day-to-day life experiences, such as whether individuals were treated with less courtesy or respect than others, received poorer service, felt as though others acted as if they did not think they were smart, or were afraid of others. Scores were calculated by reverse coding all items and averaging the scores across all six items so that the score ranged from 1 to 6, with higher numbers indicating higher levels of perceived discrimination.

Demographic and Clinical Covariates

Demographic factors also came from the biennial core interview and RAND data set. Age (in years) was treated as a continuous variable. Race/ethnicity was based on self-report and categorized as non-Hispanic white, non-Hispanic black, Hispanic, and other minority. Marital status was dichotomized into yes/living with a partner or no. Education was categorized as no degree, high school diploma/general education development (GED), and higher education. Household income and assets were reported by individuals and grouped into quartiles. Health insurance was categorized into a dichotomous variable, with any type of insurance categorized as insured. Each of these variables were based on the current survey wave and treated as fixed. Comorbidity count was treated as a time-varying covariate and was based on the count of the following diseases at each reporting period: high blood pressure, cancer, lung disease, heart condition, stroke, emotional/psychiatric problems, arthritis, and obesity. Emotional/psychiatric problems included whether a doctor ever told the respondent that they had any emotional, nervous, or psychiatric problem. Obesity was defined based on the BMI, with individuals having a BMI $\geq$35 kg/m^2 categorized as obese. Given the high mean and median BMI within this population (mean 30.1 kg/m^2, median 30 kg/m^2), class II obesity was chosen as the cut point for the obesity variable.

Statistical Analysis

To analyze the longitudinal relationship between social determinants and glycemic control, we fit a series of hierarchical linear mixed models using SAS PROC GLIMMIX. To control for nonindependence among the repeated observations for each individual, we used a random intercept model and treated each individual participant as a random factor. Unstructured covariance structure was chosen on the basis of comparing the Akaike information criterion over

different covariance structures, and time was not included as a covariate. We first explored all independent variables as fixed by using baseline information (first EFTF interview), then explored all independent variables as time varying by using all measures from surveys. For the final hierarchical models, we first fit a model with the social determinant factors, which included financial hardship variables (difficulty paying bills, food insecurity, medication cost nonadherence), positive psychosocial factors (religiosity, positive social support, efficacy over health), negative psychosocial factors (depression, negative social support, loneliness), positive environmental factors (social cohesion, social participation), and negative environmental factors (neighborhood physical disorder, perceived everyday discrimination). Second, we fit a model that included the social determinant factors and demographics (age, sex, race/ethnicity, education, household income/assets). Third, we fit a model that further added comorbidities and health insurance. Finally, we fit a standardized, fully adjusted model to understand the relative strength of each significant relationship. All *P* values were two-sided, and $P < 0.05$ was considered statistically significant. Statistical analysis was performed with SAS 9.4 software (SAS Institute).

Table 1—Sample demographics at baseline of older adults with diabetes ($n = 2,662$)

	Value
Age (years), mean (SD)	69.3 (9.13)
Sex	
Male	44.7
Female	55.3
Race/ethnicity	
Non-Hispanic white	65.5
Non-Hispanic black	18.8
Hispanic	13.0
Other	2.7
Education level	
No high school diploma	34.4
High school diploma	46.5
Higher education	19.1
Married or living with a partner	
Yes	63.3
No	36.7
Household income and assets ($), mean	
First quartile	18,400
Second quartile	99,456
Third quartile	271,905
Fourth quartile	1,119,095
Comorbidity count*	
Mean (SD)	2 (1.33)
Low comorbidity (0–1)	22.4
Moderate comorbidity (2–3)	55.9
High comorbidity (≥4)	21.7

Data are % unless otherwise indicated. *Comorbidity count includes high blood pressure, cancer, lung disease, heart condition, stroke, emotional/psychiatric problems, arthritis, and obesity.

RESULTS

The sample included 2,662 adults with diabetes and was approximately evenly split across sexes with a mean age at baseline of 69 years. The majority of the sample was non-Hispanic white (65.6%) and married or living with a partner (63.3%), and more than one-half had a high school diploma (46.5% with high school diploma/GED and 19.1% with higher education). More than one-half (56.0%) had two to three comorbidities at baseline. Further demographic information can be seen in Table 1.

Table 2 provides summary information on glycemic control and social determinant factors. The mean HbA_{1c} was 6.9%, with approximately one-third having uncontrolled diabetes using a cut point of HbA_{1c} <7% (32.7%) and 14.7% having uncontrolled diabetes using a cut point of HbA_{1c} <8%. In addition, 31.2% indicated difficulty paying bills, 13.8% indicated medication cost nonadherence, and 4.7% indicated food insecurity.

Table 3 provides results of the longitudinal mixed model to understand the influence of social determinants on glycemic control. In unadjusted analyses, significant relationships existed between higher HbA_{1c} over time and difficulty paying bills ($\beta = 0.23$ [95% CI 0.15, 0.32]), medication cost nonadherence (0.28 [0.18, 0.39]), food insecurity (0.21 [0.04, 0.38]), depression (0.03 [0.01, 0.04]), negative social support (0.09 [0.001, 0.17]), and loneliness (0.11 [0.04, 0.18]). Significant relationships existed between lower HbA_{1c} over time and efficacy over health (−0.02 [−0.03, −0.001]) and social cohesion (−0.04 [−0.06, −0.01]). In the first model incorporating financial hardship and social determinant variables, difficulty paying bills (0.19 [0.10, 0.28]) and medication cost nonadherence (0.27 [0.15, 0.38]) were independently associated with increasing HbA_{1c} over time. Before adjustment for demographics, social cohesion was also independently associated with lower HbA_{1c} over time (−0.05 [−0.10, −0.001]); however, neither medication cost nonadherence nor social cohesion were significant after adjusting for age, sex, race/ethnicity, education, and income. After adjusting for demographics, comorbidity count, and health insurance, difficulty paying bills (0.13 [0.02, 0.24]) and higher religiosity scores (0.04 [0.001, 0.08]) were independently associated with increasing HbA_{1c} over time.

Table 4 provides results from the standardized model that was fully adjusted for social determinant factors, demographics, and comorbidity count. Standardized coefficients can be interpreted as the SD increase in the independent variable that results in a 0.10-SD increase in HbA_{1c} over time. The strongest contributor in the fully adjusted model was race/ethnicity ($\beta = 0.23$ [95% CI 0.12, 0.34] for non-Hispanic blacks and 0.21 [0.07, 0.34] for Hispanics), followed by sex (−0.12 [−0.20, −0.04]) and difficulty paying bills (0.09 [0.02, 0.17]). Supplementary Fig. 1 provides information on glycemic control over time for those with and without difficulty paying for bills. On the basis of this image, those with difficulty paying bills have consistently worse glycemic control over time.

CONCLUSIONS

Using a longitudinal cohort of older adults with diabetes, this study found that financial hardship factors, such as difficulty paying bills, were more consistently associated with increasing HbA_{1c} over time than psychosocial and neighborhood factors. After adjusting for multiple social determinant factors,

Table 2—Baseline glycemic control and social demographic factors in total sample

	Mean (SD) or %	Items (*n*)	Score range	Multiple measures
Baseline blood HbA_{1c}				
Mean (SD)	6.88 (1.46)			
<7.0%	67.3			
<8.0%	85.3			
Difficulty paying bills		1	0–1	2006–2014, 5 times
Yes	31.2			
Medication cost nonadherence		1	0–1	2006–2014, 5 times
Yes	13.8			
Food insecurity		2	0–1	2006–2014, 5 times
Yes	4.7			
Perceived social support positive	3.11 (0.55)	12	1–4	2006–2014, 5 times
Religiosity	5.12 (1.29)	4	1–6	2006–2014, 5 times
Efficacy over health	6.86 (2.49)	1	0–10	2006–2014, 5 times
Perceived social support negative	1.70 (0.50)	16	1–4	2006–2014, 5 times
Depression score	1.83 (2.18)	7	0–8	2006–2014, 5 times
Loneliness	1.57 (0.58)	3	1–3	2006–2014, 5 times
Neighborhood social cohesion	5.28 (1.47)	4	1–7	2006–2014, 5 times
Social participation	7.39 (3.27)	18	0–18	2008–2014, 4 times
Neighborhood physical disorder	2.70 (1.42)	4	1–7	2006–2014, 5 times
Everyday discrimination	1.72 (0.83)	5	1–6	2006–2014, 5 times

demographics, and comorbidities, difficulty paying bills maintained an independent association with increasing HbA_{1c} over time. In addition, a higher religiosity score was independently associated with increasing HbA_{1c} over time, despite this variable being theoretically considered a positive psychosocial factor. The three strongest contributors to longitudinal glycemic control were race, sex, and difficulty paying bills, with those having difficulty paying bills associated with a 0.09-SD increase in HbA_{1c} over time.

This study adds important information to the literature on the relationship between social determinants and diabetes outcomes for older adults. First, it highlights the importance of financial hardship on glycemic control over time and, hence, complications and poor outcomes in the future. Prior cross-sectional studies demonstrated that at least 10% of patients with chronic conditions, including diabetes, have financial barriers to optimal treatment (10–13). Many of the financial barriers stem from the complexity of diabetes care, such as the need for multiple medications, diabetes supplies, and healthy food (12,13). Our research adds to this topic by describing one of the first longitudinal studies to show a consistent influence of difficulty paying bills on diabetes outcomes over time despite adjustment for multiple confounders. Possible mechanisms regarding the relationship between financial hardship and glycemic control include increased stress associated with competing needs for financial resources, lack of material needs important in maintaining long-term health, and decreased self-care, as other pressing needs, such as employment or family structures, requiring support take precedence over one's health (7,8,21,27). These mechanisms need investigation to better target health-related interventions that address social concerns, particularly those surrounding measures such as difficulty paying bills, which were found to be significant in this analysis but have limited research on potential mechanisms.

In addition, this study suggests that psychosocial and neighborhood influences, such as social cohesion and religiosity, may have a relationship with glycemic control over time. We found that before adjustment for demographics, higher social cohesion was associated with lower HbA_{1c}. This aligns with prior research noting a relationship between social cohesion and reduced odds of having hypertension and type 2 diabetes as well as improved glycemic control in patients with diabetes (17,24,25). While religiosity has been shown to provide health benefit overall, this is one of the first studies to find a significant relationship between religiosity and glycemic control after adjustment. Murray-Swank et al. (36) found that attendance at religious services and having regular contact with a religious leader were not associated with HbA_{1c} levels. Similarly, How et al. (37) did not find a significant association between religiosity and HbA_{1c} level, although they found that the type of religion was associated with HbA_{1c}. There is some evidence that certain religious coping styles may be detrimental to health, which would align with results from this study. For example, belief that illness is a punishment from God can have a detrimental impact on physical health outcomes (38). The majority of research on religiosity has focused on mental health and is associated with positive relationships (38). Given these findings, more research is needed in this area to understand the aspects of religiosity that may be either positively or negatively associated with health and whether this differs for physical versus mental health.

Given the increased attention to incorporate social determinants of health into interventions addressing diabetes outcomes, these results suggest a number of possible targets. First, future intervention studies should explore offering financial incentives to people with uncontrolled diabetes experiencing financial hardship and examine the impact on outcomes. For example, a study on the effect of financial incentives on glycemic control among young adults with uncontrolled type 1 diabetes showed significantly greater adherence to glucose monitoring during the intervention period (39). An ongoing randomized controlled trial in Singapore is

Table 3—Longitudinal relationship between social determinants of health and glycemic control

	Model 1	Model 2	Model 3
Difficulty paying bills*	**0.18 (0.07, 0.29)**	**0.13 (0.02, 0.24)**	**0.13 (0.02, 0.24)**
Medication cost nonadherence*	**0.15 (0.01, 0.29)**	0.11 (−0.03, 0.25)	0.11 (−0.03, 0.25)
Food insecurity*	0.16 (−0.06, 0.38)	0.14 (−0.08, 0.37)	0.15 (−0.07, 0.38)
Religiosity**	0.03 (−0.004, 0.07)	0.04 (−0.002, 0.07)	**0.04 (0.001, 0.08)**
Positive social support**	−0.03 (−0.12, 0.07)	−0.02 (−0.11, 0.08)	−0.02 (−0.1,1 0.08)
Efficacy over health**	0.002 (−0.02, 0.02)	−0.003 (−0.02, 0.02)	−0.01 (−0.03, 0.01)
Depression score**	−0.01 (−0.03, 0.02)	−0.004 (−0.03, 0.02)	0.001 (−0.03, 0.03)
Negative social support**	0.01 (−0.10, 0.13)	−0.03 (−0.14, 0.08)	−0.03 (−0.14, 0.09)
Loneliness**	0.05 (−0.05, 0.15)	0.07 (−0.03, 0.17)	0.08 (−0.03, 0.18)
Neighborhood social cohesion**	**−0.05 (−0.10, −0.001)**	−0.04 (−0.09, 0.01)	−0.04 (−0.09, 0.01)
Social participation**	−0.01 (−0.02, 0.01)	−0.01 (−0.02, 0.01)	−0.01 (−0.02, 0.01)
Neighborhood physical disorder**	−0.04 (−0.09, 0.01)	−0.04 (−0.09, 0.005)	−0.04 (−0.09, 0.01)
Everyday discrimination**	0.01 (−0.06, 0.08)	−0.003 (−0.07, 0.06)	−0.00 (−0.07, 0.07)
Age**		**−0.01 (−0.02, −0.004)**	**−0.01 (−0.02, −0.001)**
Sex (reference = male)		**−0.17 (−0.28, −0.06)**	**−0.16 (−0.27, −0.05)**
Race/ethnicity (reference = non-Hispanic white)			
Non-Hispanic black		**0.33 (0.18, 0.48)**	**0.32 (0.17, 0.47)**
Hispanic		**0.32 (0.13, 0.50)**	**0.29 (0.10, 0.47)**
Other		0.27 (−0.06, 0.59)	0.25 (−0.07, 0.58)
Education (reference = no degree)			
High school diploma/GED		0.07 (−0.07, 0.21)	0.07 (−0.07, 0.21)
Higher education		0.06 (−0.12, 0.23)	0.05 (−0.13, 0.23)
Household income and assets (reference = first quartile)			
Second quartile		0.06 (−0.08, 0.19)	0.05 (−0.09, 0.19)
Third quartile		−0.05 (−0.20, 0.10)	−0.07 (−0.22, 0.08)
Fourth quartile		−0.03 (−0.19, 0.14)	−0.05 (−0.22, 0.11)
Comorbidity count**			**−0.05 (−0.09, −0.01)**
Health insurance*			−0.05 (−0.24, 0.14)

Data are unstandardized coefficients with 95% CIs. Bold text indicates significance at $P < 0.05$. Model 1 includes social determinant variables. Model 2 adds demographics. Model 3 adds comorbidity count and health insurance. *Categorical variable with reference of no. **Continuous variable with coefficient based on one increase in unit of measurement.

examining the impact of either process incentives or outcome incentives compared with usual care on glycemic control, self-care behaviors, and medication adherence (40). Research is needed regarding the type of incentive that will be most influential in improving health; however, studies of financial incentives in other diseases suggests that care must be taken to understand the nature of the behavior being incentivized, communicate information regarding the incentive to make it more effective, provide incentives that are appropriately sized to motivate behavioral change, and incorporate aspects that promote intrinsic motivation by combining financial and nonfinancial incentives (41,42). Second, studies are needed to understand how health care professionals can take financial hardship factors, such as the inability to pay bills, into account during a clinical encounter. According to a position paper by the American College of Physicians, a better understanding by health care providers is essential in the pursuit of reducing the negative outcomes associated with social determinants of health (42). The factors, however, are often outside the scope of the health care system, and without an understanding of how these factors influence patient outcomes, providers may be unlikely to directly address these concerns in the clinical encounter.

Although this study used a longitudinal cohort and incorporated a wide variety of social determinant factors, there are limitations to these results that should be considered. First, the data were collected from individuals ≥50 years old, so they may not be appropriate to generalize to younger populations with diabetes. Particularly given the influence of socioeconomic status over the lifetime, future studies should collect longitudinal information on cohorts from early adulthood through later life. In addition, the population had high levels of controlled diabetes, relationships in populations with more uncontrolled diabetes may differ. Second, while financial hardship, psychosocial, and neighborhood factors were included, additional social determinants could influence glycemic control that were not collected in this data set. For example, future work should consider collecting information on food access and exercise opportunities. Third, social determinant factors were analyzed using summary measures as defined by the HRS documentation for each individual variable. Future studies should consider investigating the individual factors using exploratory and/or confirmatory factor analysis to determine whether some variables have multiple constructs that should be incorporated in analyses separately. This may provide additional insight into how social determinants of health influence outcomes. Future studies should also incorporate different scales; for example, rather than using a single question for food insecurity, incorporation

Table 4—Standardized model for longitudinal relationship between social determinants of health and glycemic control

	Fully adjusted model
Difficulty paying bills*	**0.09 (0.02, 0.17)**
Medication cost nonadherence*	0.08 (−0.02, 0.18)
Food insecurity*	0.11 (−0.05, 0.27)
Religiosity**	**0.04 (0.001, 0.07)**
Positive social support**	−0.01 (−0.04, 0.03)
Efficacy over health**	−0.01 (−0.05, 0.03)
Depression score**	0.02 (−0.04, 0.05)
Negative social support**	−0.01 (−0.05, 0.03)
Loneliness**	0.03 (−0.01, 0.07)
Neighborhood social cohesion**	−0.04 (−0.09, 0.01)
Social participation**	−0.01 (−0.05, 0.02)
Neighborhood physical disorder**	−0.04 (−0.10, 0.01)
Everyday discrimination**	−0.00 (−0.04, 0.04)
Age**	**−0.06 (−0.10, −0.02)**
Sex (reference = male)	**−0.12 (−0.20, −0.04)**
Race/ethnicity (reference = non-Hispanic white)	
Non-Hispanic black	**0.23 (0.12, 0.34)**
Hispanic	**0.21 (0.07, 0.34)**
Other	0.18 (−0.05, 0.41)
Education (reference = no degree)	
High school diploma/GED	0.05 (−0.05, 0.15)
Higher education	0.04 (−0.09, 0.16)
Household income and assets (reference = first quartile)	
Second quartile	0.04 (−0.06, 0.13)
Third quartile	−0.05 (−0.16, 0.06)
Fourth quartile	−0.04 (−0.16, 0.08)
Comorbidity count**	**−0.05 (−0.09, −0.01)**
Health insurance*	−0.04 (−0.17, 0.10)

Data are standardized coefficients with 95% CIs. Bold text indicates significance at $P < 0.05$. Model includes social determinant variables, demographics, comorbidity count, and health insurance. *Categorical variable with reference of no. **Continuous variable with coefficient based on one increase in unit of measurement.

of the six-item U.S. Department of Agriculture food insecurity questionnaire may provide more robust measurement of food insecurity. The low prevalence of food insecurity in this population may be due in part to the general population nature of HRS rather than, for instance, to a focus on only Medicare populations (43,44), but it may also be due to underreporting that can result from a less comprehensive measure of food insecurity that incorporates the stress and distress in addition to the inability to afford food. Fourth, all social determinant factors were self-reported. Some variables, such as physical disorder within neighborhoods, can be assessed in using an objective measure and should be considered in future analyses. Finally, the glycemic control in this cohort was relatively good, with a mean just below 7%. Therefore, populations with more higher levels of uncontrolled diabetes may show a different relationship between social determinants and glycemic control and should be targeted in future cohorts.

In conclusion, we found that social determinants of health have a longitudinal influence on diabetes outcomes in a cohort of older adults followed from 2006 to 2014. After adjusting for multiple social determinant factors, demographics, and comorbidities, difficulty paying bills maintained an independent association with increasing HbA_{1c} over time. These findings suggest that financial hardship in particular is an important determinant of diabetes outcomes and provide guidance regarding possible targets for future work.

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